Abstract

Plant–animal interaction systems are complex food webs where the members—plants, pollinators, herbivores, parasites and predators of the pollinators/herbivores—interact with each other in ways which maximize their own fitness. Based on the net outcome, such interactions could be mutually beneficial to the interacting members (mutualism) or beneficial to only one of the interacting members at the cost of the other interacting members (herbivory, predation, parasitism). It is possible that such outcomes are actually a continuum and could swing in either direction from beneficial to detrimental and vice versa. Such transitions happen not only over long time scales, but could also happen within shorter time scales based on conditionalities. Conditional outcomes are those in which the outcome of an interaction between two partners is conditional on the involvement of a third partner. Thus, studying such outcomes necessitates taking into account systems beyond the classical two-partner interactions.

In such complex multitrophic plant–animal interaction systems in which there are direct and indirect interactions between species, comprehending the dynamics of these multiple partners is very important for an understanding of how the system is structured. In **Chapter 2** we investigate *Ficus racemosa* and its community of obligatory mutualistic and parasitic fig wasps that develop within the fig inflorescence or syconium, as well as their interaction with opportunistic ants. We focus on temporal resource partitioning among members of the fig wasp community over the development cycle of the fig syconia during which wasp oviposition and development occur and we study the activity rhythm of the ants associated with this community. We found that the members of the wasp community partitioned their oviposition across fig syconium development phenology and showed interspecific variation in activity across the diel cycle. The wasps presented a distinct sequence in their arrival at fig syconia for oviposition. We documented night oviposition in several fig wasp species for the first time. Ant activity on the fig syconia was correlated with wasp activity and was dependent on whether the ants were predatory or trophobiont-tending species; only numbers of predatory ants increased during peak arrivals of the wasps.

In **Chapter 3**, we found that predatory ants (*Oecophylla smaragdina*) patrolling *F. racemosa*

trees were attracted to the odour from fig syconia at different developmental phases, as well as to the odours of fig wasps, whereas other predatory ants (*Technomyrmex albipes*) responded only to odours of syconia from which fig wasps were dispersing and to fig wasp odour. However, trophobiont-tending ants (*Myrmicaria brunnea*) patrolling the same trees and exposed to the same volatiles were unresponsive to fig or fig wasp odours. The predatory ants demonstrated a concentration-dependent response towards volatiles from figs receptive to pollinators and those from which wasps were dispersing while the trophobiont-tending ants were unresponsive to such odours at all concentrations. Naïve predatory ants failed to respond to the volatiles to which the experienced predatory ants responded, indicating that the response to fig-related odours is learned.

In **Chapter 4** we characterise the dynamics of the volatile bouquet of the fig syconium from the initiation through pre-receptive, receptive, and late inter-floral stages which act as signals/ cues for different fig wasp species. We were also interested in diel patterns of volatile emission as some fig wasp species were strictly diurnal (the pollinator, *Ceratosolen fusciceps*) whereas other fig wasps such as *Apocryptophagus fusca* were observed ovipositing even during the nocturnal hours. We identified volatiles that were specific to syconium development phase as well as to the time of day in this bouquet. α-muurolene was identified as the sesquiterpene specific to receptive-phase as well as being present only during the day thus coinciding with the diurnal pollinator arrival pattern. Volatiles such as (*E*)-β-ocimene were present in increasing levels across the developmental stages of the fig and thus could act as background volatiles providing suitable information to fig wasps about host plants and their phases.

Chapter 5 examines the responses of predatory and trophobiont-tending ant species to the cuticular hydrocarbon (CHC) extracts of four galler and two parasitoid fig wasp species associated with *F. racemosa*. Interestingly, the antennation response of both experienced and naïve ants to these wasp extracts was identical indicating that prior exposure to such compounds is not necessary for eliciting such response. We also characterised these cuticular hydrocarbon extracts to find potential compounds which could as short-range cues for predatory ants. Ants were more responsive to the cuticular extracts of parasitoids rather than to those of galler wasps, implying that the CHC profile of carnivorous prey may contain more elicitors of aggressive

behaviour in ants compared to herbivorous prey whose profiles may be more similar to those of their plant resources. We also find congruency between the cuticular profiles of parasitoids and their hosts suggesting that parasitoids could sequester compounds from their diet.

Important findings and conclusions of the thesis are presented in **Chapter 6**.

The first two parts of the appendices section discuss work carried out on alternative ways of analysing multivariate data sets such as plant volatiles and insect cuticular hydrocarbons. **Appendix A** details the use of Random Forests, an algorithm-based method of analysing complex data sets where there are more variables than samples, a situation akin to microarray data sets. This work illustrates the use of such techniques in chemical ecology, highlighting the potential pitfalls of classical multivariate tests and the advantages of newer more robust methods. **Appendix B**, an invited article following the publication of the earlier work, compares different data transformation procedures currently employed in such multivariate analysis.

Appendix C details sex-specific differences in cuticular hydrocarbons of fig wasps, using the pollinator *C. fusciceps* as a case study.